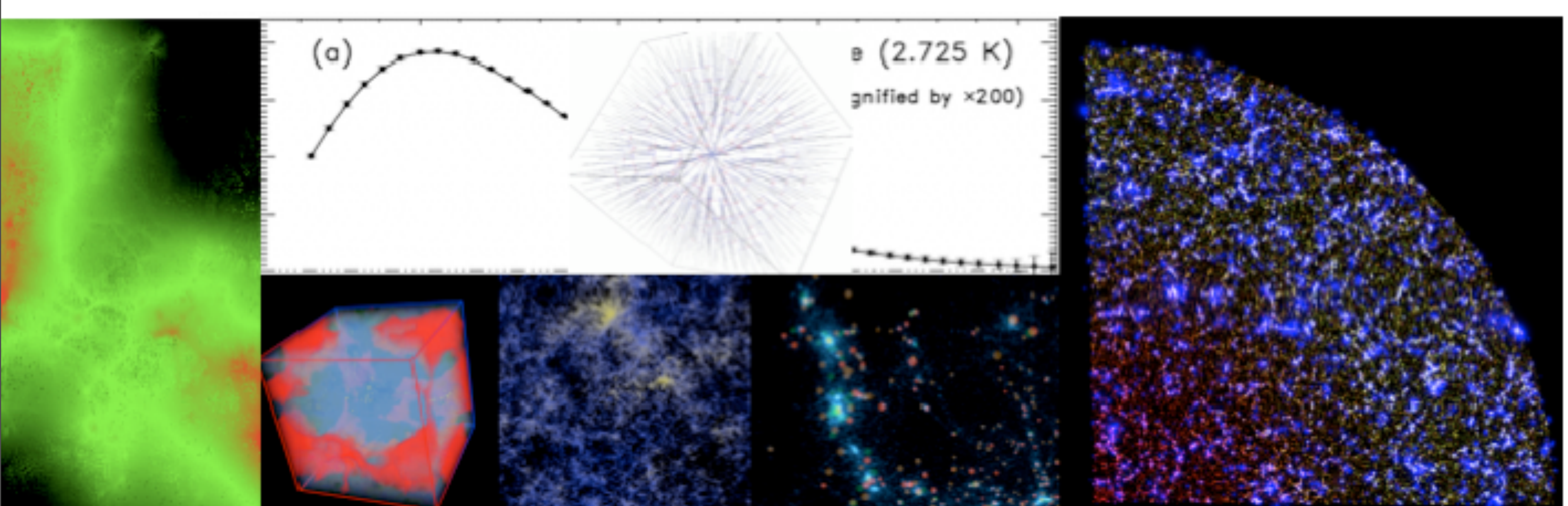
Computational Cosmology Collaboration at the DOE HEP Labs

Salman Habib



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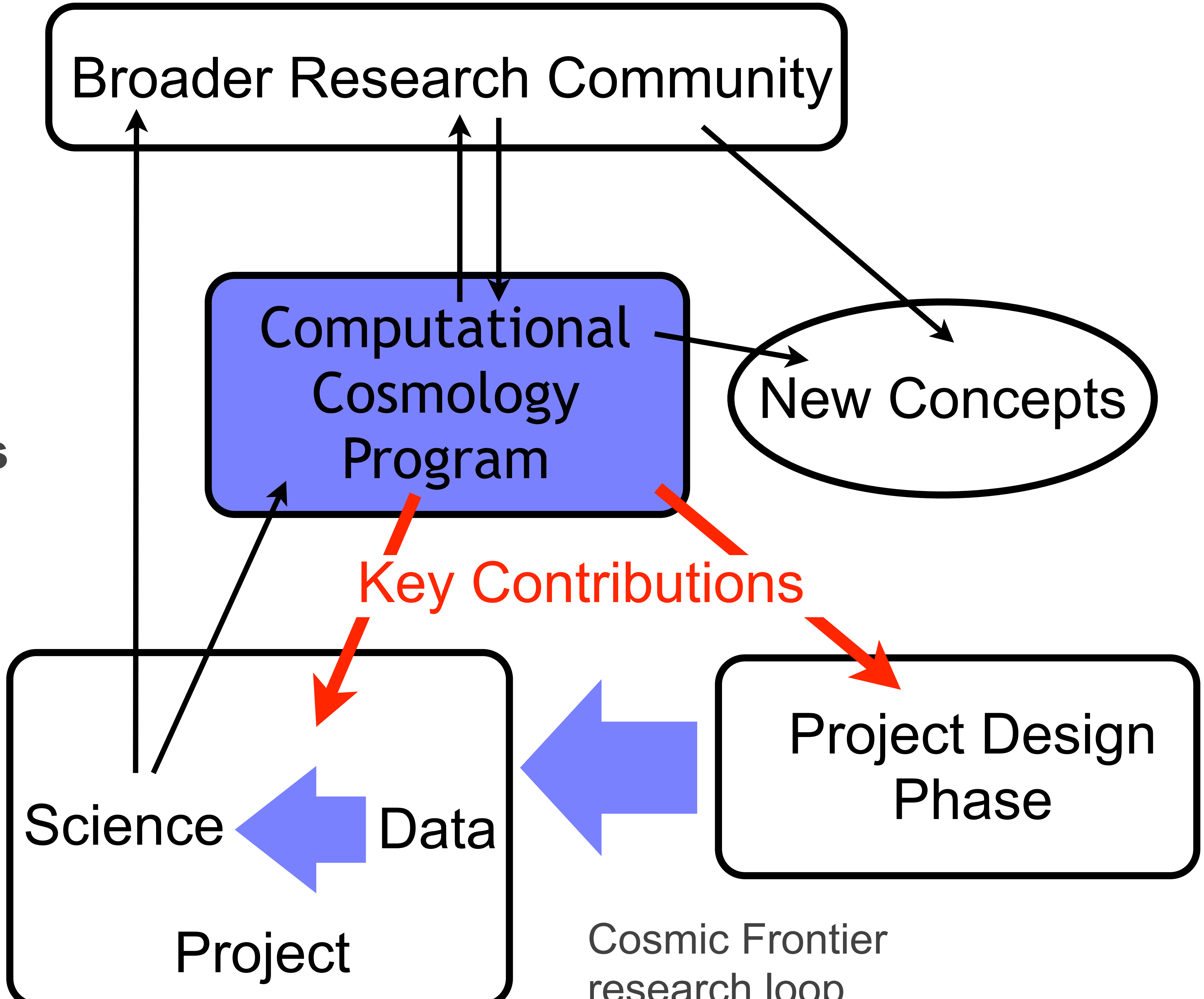
Motivation

- Cosmology provides a unique repository of information regarding fundamental physics. To access this repository requires a coordinated and disciplined core capability program of cosmological theory, modeling and simulations -- as well as associated data analysis -- to help interpret the results of upcoming experiments such as DES and LSST; it will also extend their science reach
- The DOE Labs (augmented with university partnerships as appropriate) are ideal institutions to support and provide this function
- We are now building a collaborative program across ANL, BNL, FNAL, LBNL, and SLAC to address the central mission (in partnership with Lab management and DOE HEP)

Role of the Collaboration as a Core Program in DOE HEP

- Resides as a core capability program within DOE HEP
- Contributes to 'discovery space'
- Catalyzes development of concepts into projects
- Plays a key role in project optimization
- Is an essential component of the **'Data to Science'** step for projects
- Functions as a major community resource

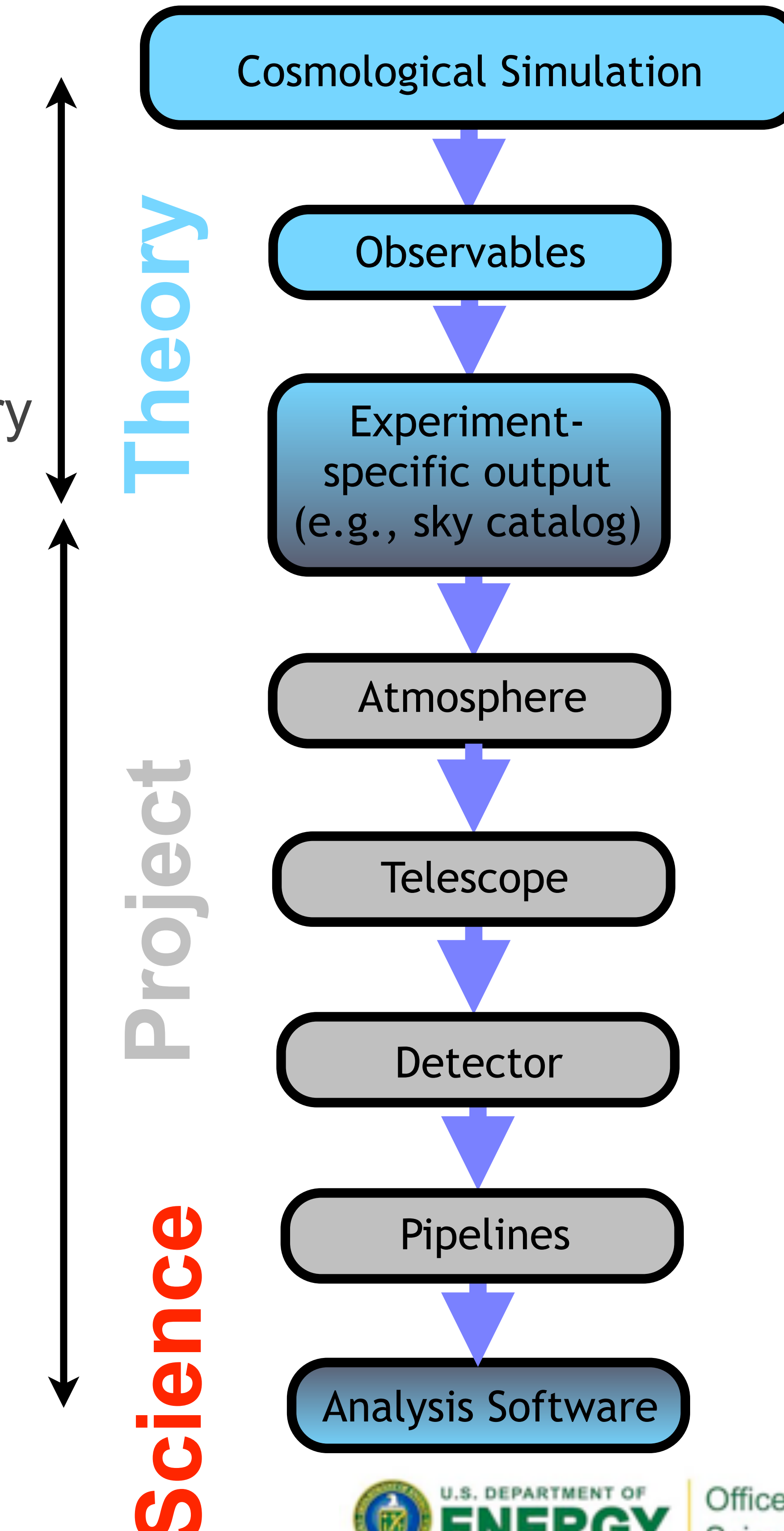


Cosmic Frontier research loop

Advantages of a Core Program

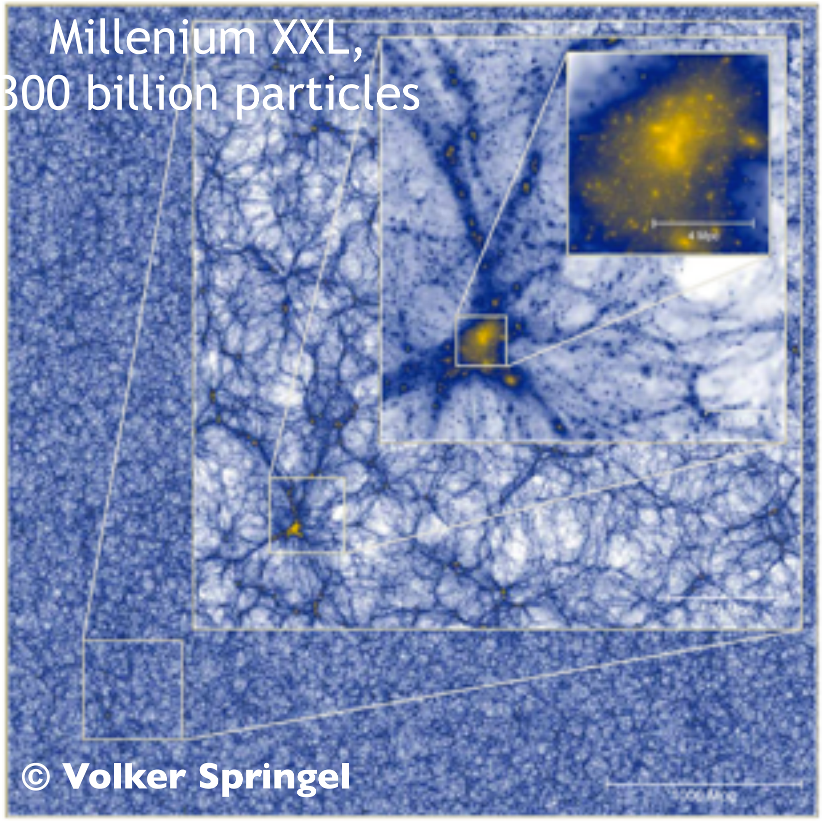
- Key Roles
  - One-point contact for scientists, projects, and programs
  - In-house theory, modeling, and simulation capability
  - Connection to HEP computing
  - Efficient collaboration, ability to work to milestones/time tables
  - Repository of ‘Lessons Learnt’ and ‘Best Practices’ (crucial in precision cosmology)
  - Continuous development paths
  - Develop and maintain simplified ‘detector model’ views of project space (hunt for subtle signals)
  - Connections across projects (joint analyses)

Notional theory and project task division



Computational Paradigm I

- **N-body, gravity only:** At large scales (>~1 Mpc), gravity is the dominant force and remains important down to the smallest scales
  - **Methods:** Modern codes are parallel solvers for the Vlasov-Poisson equation, employing particle and grid techniques, often together
- **'Hydrodynamics':** Addition of baryonic physics
  - **Methods:** Eulerian (typically AMR) or Lagrangian (typically SPH); feedback processes and sub-grid models (chemistry, star formation), other physics (e.g., MHD) introduced as appropriate
- **Scales:** Code runs can cover scales as small as resolving individual galaxies to box sizes at the horizon scale (several Gpc to a side)
- **Analysis:** Many compute-intensive techniques (real-time/post-processing): ray-tracing, N-point statistics, halo/sub-halo finders, merger-trees, --



Simplified DES catalog flow chart

- simulation
- halo finding
- merger trees
- assign galaxies
- compute shear
- lens galaxies
- photometric errors
- photo-z
- sky images

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Computational Paradigm II

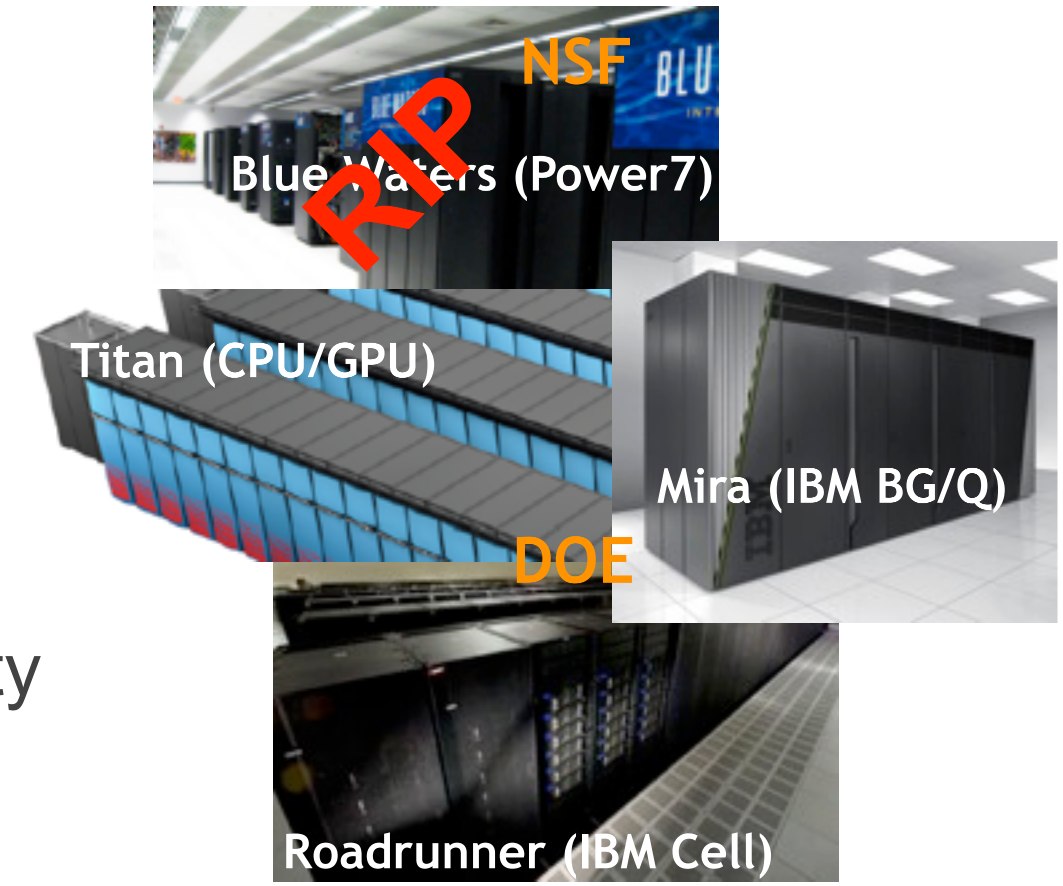
Algorithms: Improvements are focus of major effort by the computational community (not just cosmologists, e.g., beam physics, CFD, plasma physics --)

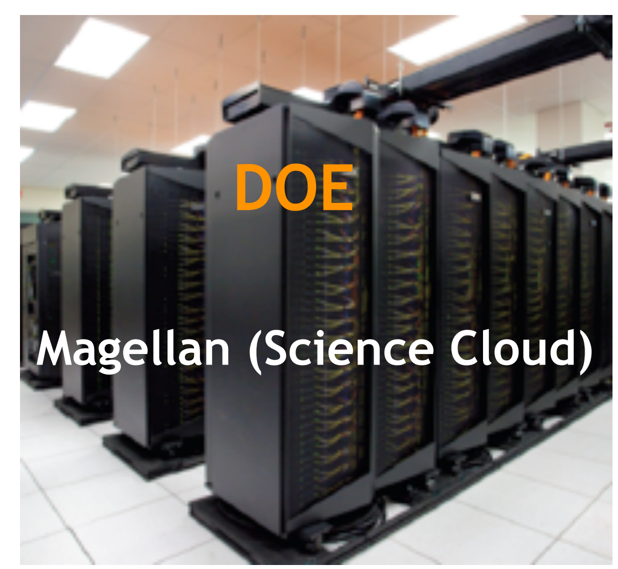
Hardware evolution: Radical architecture changes, new programming models and imperatives in the near future

- **Code future:** How will codes evolve, community response needed
- **Ecology:** Current code mix may shrink as development goes over to the team model
- **Job mix:** Leadership-class vs. large numbers of large/medium job ensemble runs

Data-intensive applications: Data-specific platforms already available ('cloud')

- **Optimal mix:** Very important for future surveys, especially LSST (HEP/ASCR report)





Data-intensive systems

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Synergies

- **Many synergies with other programs in DOE HEP and other Offices**
  - **HEP Experiments:** Large data, high throughput computing, workflows, software infrastructure (possible workshop?)
  - **Accelerator Modeling:** Several common threads -- particle simulation codes, radiation, emulation, parallel optimizations, I/O, etc. (Accelerator people suggest joint workshop)
  - **NNSA Labs:** Existing collaborations and opportunities in domain science and CS (simulations/algorithms/data)
  - **DOE ASCR:** Several important points of contact in applied math, HPC software, I/O, large data
  - **NASA/NSF:** Collaborations with NASA and NSF supported activities as appropriate

Planning Steps and Actions I

- **Results from meeting at LBNL (August)**
  - **Science/Infrastructure Organization:** Basic organization on three strongly overlapping themes: [1] Simulations, [2] Middleware/Tools, and [3] Cosmological Probes. POCs from each Lab were named, cross-membership in these teams is expected and encouraged
  - **Collaborative Activities:** Consensus on several collaboration topics (tasks for Simulations & Middleware teams)

  [1] Generation/sharing of initial conditions (single IC code framework)

  [2] Improve interoperability

  [3] Develop “CosmoPack”, multi-algorithmic set of HPC kernels

  [4] Exchange expertise on code development and analysis

  [5] Data serving capabilities (remote analysis to follow)

  [6] Build the “SkyShop” (simulation database list)

  [7] Cross-Lab network connectivity

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Planning Steps and Actions II

- **Collaborative Science Areas:** List covers essentially all of DOE HEP's Cosmic Frontier program, Cosmological probes team to prioritize
- **Support Infrastructure:** Resource availability and planning; includes software, hardware, and people support, including best balance of local and remote resources (this last varies across the Labs)
- **Staffing profiles:** Initiated discussion on future staffing profiles in the area at the Labs (general result: 1-2 FTE/Lab hires in near future considered desirable)
- **NERSC and Other Computing Opportunities:** NERSC 'cosmosim' repo established; material collected for NERSC allocation proposal due Sep 23rd. ALCC and INCITE possibilities will be explored. Optimize time under ALCF ESP project; explore BNL possibilities
- **Connections to Projects:** Initiated as part of this planning meeting, will continue --

Summary

- **Leadership position for DOE HEP in computational cosmology**
  - **Growth of area:** Field is rapidly expanding, but still lacks coherence
  - **Need for Computational Cosmology Program:** Articulated to DOE HEP by research community and national committees over the last decade -- size of collaborations and sustained effort is National Lab-scale -- Labs are now coming together and eager to formalize the planning process
  - **New opportunities:** Next-generation precision cosmology requires significant theoretical, computational, and infrastructural advances
  - **DOE Labs:** Well-placed for leadership role within national and international collaborations, computational resources available

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